Measurements of the Aerosol Light-Scattering Coefficient at Ambient and 85% Relative Humidity on the ONR Pelican During ACE-2

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LONG-TERM GOALS

The ultimate goal of this study is the determination of aerosol hygroscopicity and its impact on physical (e.g., size) and optical (e.g., scattering coefficient) properties of marine aerosols on large spatial scales. Related to this, a methodology for retrieving the dry aerosol properties from ambient measurements on large spatial scales, for example, by satellite remote sensing, is of great interest.

OBJECTIVES

Several of the objectives enumerated in previous reports have now been largely achieved (e.g., assessment of the impact of humidity on aerosol scattering coefficient for different aerosol types in ACE-2). Hence, in this report, we move on to objectives which have yet to be achieved, or have been achieved in the last year, and emphasize the more recent data sets which will be utilized to address them. In addition to the TARFOX and ACE-2 databases, results from ACE-Asia are now in hand and some data from the still ongoing RED experiment are also available. Furthermore, analyses of data gathered during the recent CALSPAN laboratory experiment (ONR sponsored) are now available to help guide the current analyses. Hence, our objectives are as follows:

- Explore the feasibility of remotely retrieving aerosol hygroscopicity (ACE-2, DECS, TARFOX, ACE-Asia).
- Explore the feasibility of a remote retrieval of dry aerosol volume and CCN number concentration (TARFOX, ACE-2, DECS, ACE-Asia).
- Explore the relationship between aerosol hygroscopicity and organic composition (ACE-Asia, possibly ACE-2).

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The ultimate goal of this study is the determination of aerosol hygroscopicity and its impact on physical (e.g., size) and optical (e.g., scattering coefficient) properties of marine aerosols on large spatial scales. Related to this, a methodology for retrieving the dry aerosol properties from ambient measurements on large spatial scales, for example, by satellite remote sensing, is of great interest.

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APPROACH

The technique used to quantify the hygroscopicity of aerosols from in-situ measurements has been described in previous reports. Similarly, the basic approach used to retrieve aerosol hygroscopicity from remote sensing measurements, namely, the use of a Look-Up Table (LUT) based on that employed by the MODIS team has been mentioned previously. The relevant details of these techniques are discussed within the context of the results.

In addition to the analyses of hygroscopicity, we have now additionally undertaken analyses of the chemical composition of the aerosol, and in particular the organic composition. Aerosol samples are first obtained by either filtration or impaction (filter packs or MOUDI impactors) and subjected to an array of analytical techniques upon return to the laboratory. These include ion chromatography with both conductivity and pulsed amperometric detectors, HPLC, and LC-MS.

WORK COMPLETED

Tasks associated with the first two objectives listed above have essentially been completed utilizing data from the TARFOX and ACE-2 data sets. Manuscripts reporting these results are now in preparation and a Ph.D. thesis based on them (Gasso, 2001) has been successfully completed. We are exploring the feasibility of applying the techniques developed to the ACE-Asia data set. Filter and impactor data from the ACE-Asia venue have been obtained and are currently undergoing laboratory analysis.

RESULTS

Two main results are now available. The first of these is derived from our analysis of the feasibility of the retrieval of aerosol hygroscopicity. Utilizing an expanded version of the MODIS LUT, including ambient RH and aerosol hygroscopicity, attempts were made to retrieve the γ parameter (see previous reports) from irradiances generated from size distributions both included and not included in the LUT. Examples of results obtained are shown in Figures 1 and 2 for included and not included distributions, respectively. It can be seen that, for included distributions, quite good retrievals were obtained at all viewing geometries and for effective radius and optical depth as well as for γ. Only η, the ratio of modal volumes for bi-modal distributions proved recalcitrant. However, for distributions not included in the LUT, the results are much more problematic. While the optical depth was still generally retrievable, γ could only be obtained for specific viewing angles—and these angles varied with the distribution examined. A principle component analysis of all retrieval calculations revealed that, in principle, hygroscopicity should be retrievable but it is clear that some other technique than a LUT will be necessary for generally valid retrievals.

The second main result concerns the retrieval of dry aerosol volume and CCN concentration. Our parameterization, which includes case specific aerosol hygroscopicity, has proven to be significantly more accurate than the algorithm now used by MODIS to obtain estimates of CCN concentration. A comparison of retrievals by two different levels of parameterization involving hygroscopicity are compared with the standard MODIS technique and direct in-situ measurements for data gathered during TARFOX (shown in Figure 3). While further refinement would be beneficial, these results are clearly encouraging.

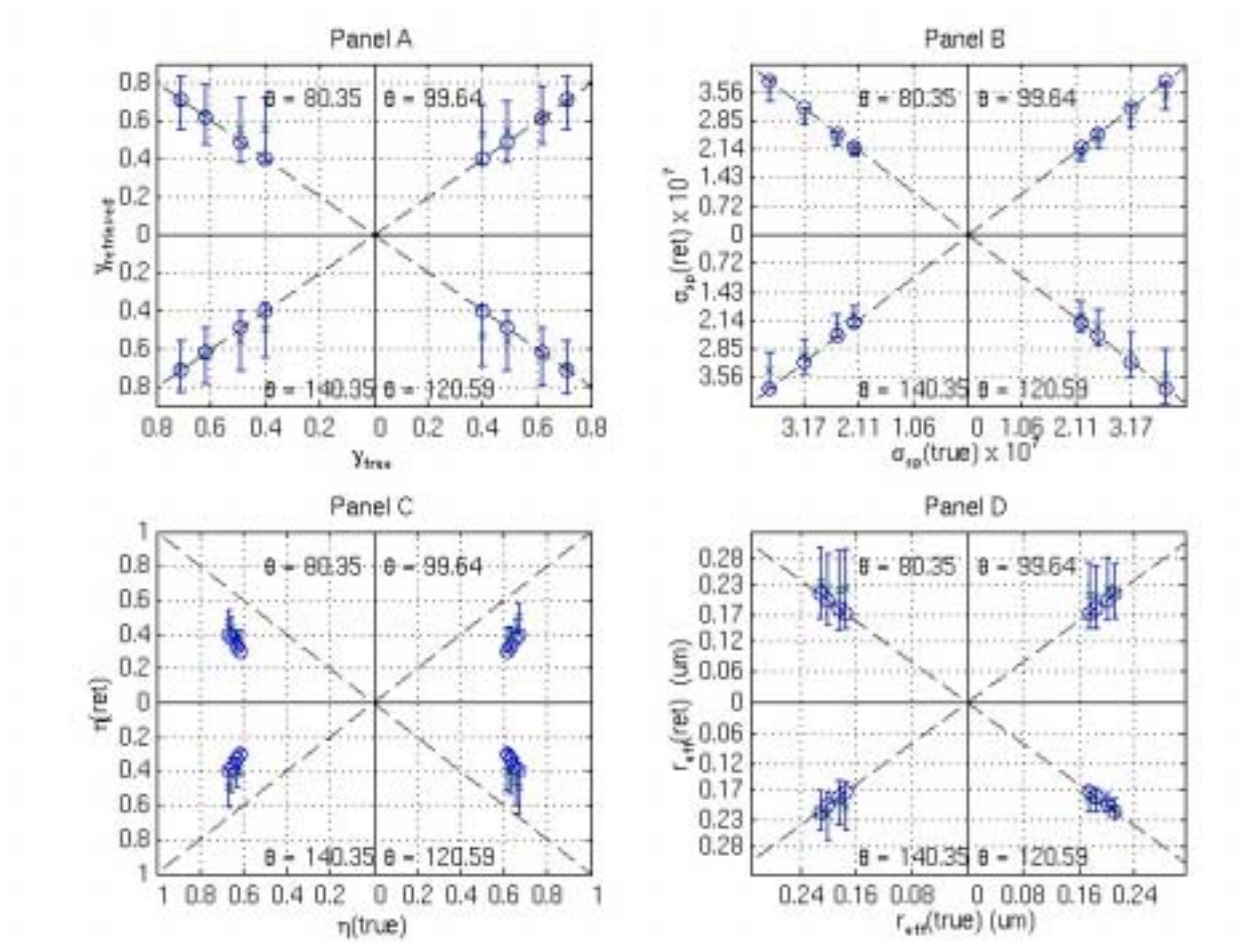

Figure 1: Comparison of retrieved values of four aerosol parameters (γ = aerosol hygroscopicity, σ_{sp} = aerosol optical depth, η = ratio of modal volumes for bi-modal distributions, r_{eff} = aerosol effective radius) with in-situ measurement. Four viewing geometries are shown for each parameter. The dotted lines in each panel are the 1:1 lines. The size distributions used were taken from those included in the MODIS LUT.

IMPACT/APPLICATIONS

These results suggest that CCN number concentration can be retrieved reasonably well in marine air if one takes into account aerosol hygroscopicity. The retrieval of hygroscopicity itself, while feasible in principle, will require development of a more sophisticated technique than a LUT. This issue is worth pursuing since the hygroscopicity plays such an important role in aerosol optical properties in marine air and measurement by more conventional means is both rare and expensive.

TRANSITIONS

For the current reporting period, it is the ACE-Asia data set which is of paramount importance. Both the hygroscopicity data and the chemical composition data generated from this data set will be of wide interest to the aerosol community.

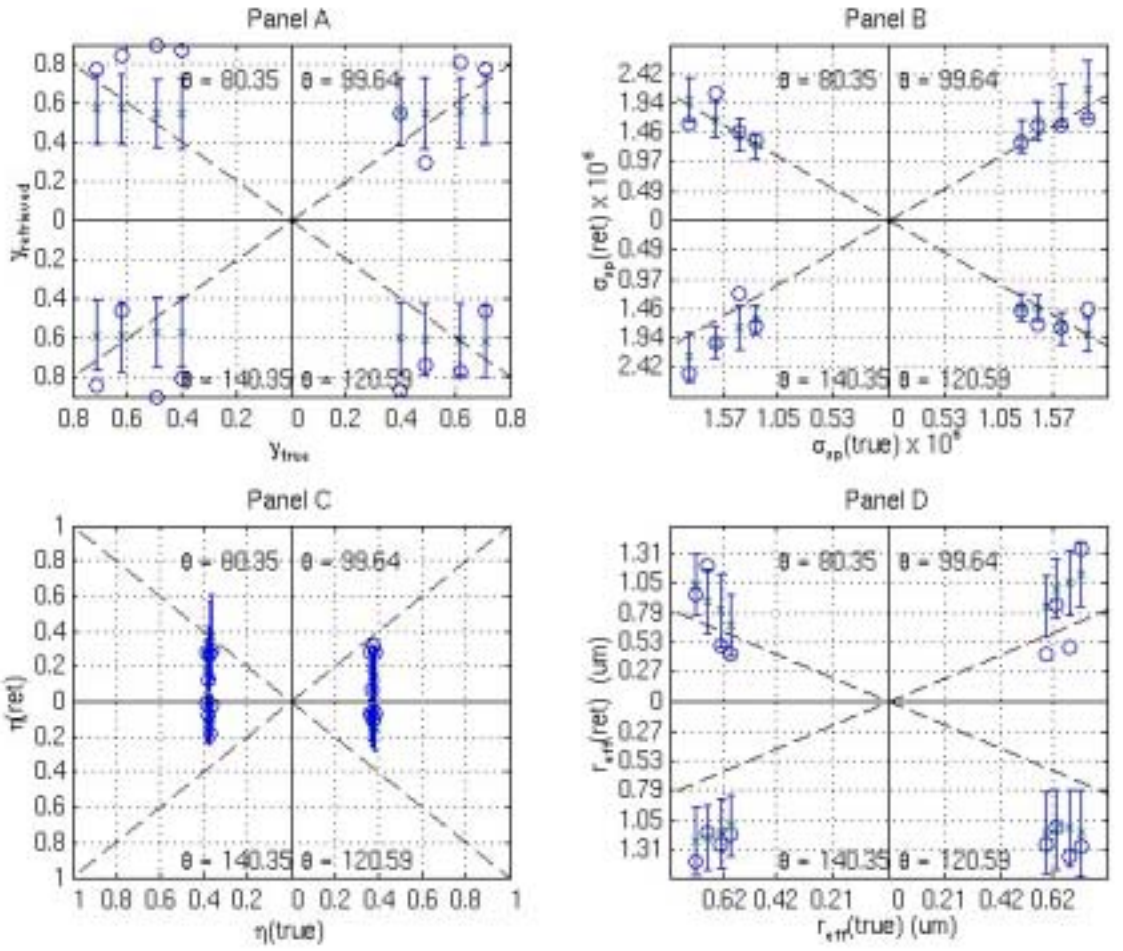

Figure 2: As in Figure 1 but for aerosol size distributions not in the MODIS LUT.

RELATED PROJECTS

The use of aerosol hygroscopicity and associated optical data (e.g., scattering and absorption coefficients for ambient aerosols) is of great interest to various research groups. For example, we are currently cooperating with Phil Russell's group at NASA-Ames in a closure study of aerosol optical depth based on the ACE-Asia data set. Similarly, retrieval of both aerosol hygroscopicity and CCN concentration are of great interest to the remote sensing community and we are cooperating with scientists from the MODIS team on this issue.

SUMMARY

Our work over the last year has lead to several conclusions which constitute advances in our knowledge relative to a year ago.

- Aerosol hygroscopicity is remotely retrievable but not by a LUT except in certain specific situations.

- More standard aerosol properties such as effective radius and the ratio of modal volumes in a bi-modal distribution cannot generally be retrieved by a LUT except for aerosol size distribution included in the LUT.

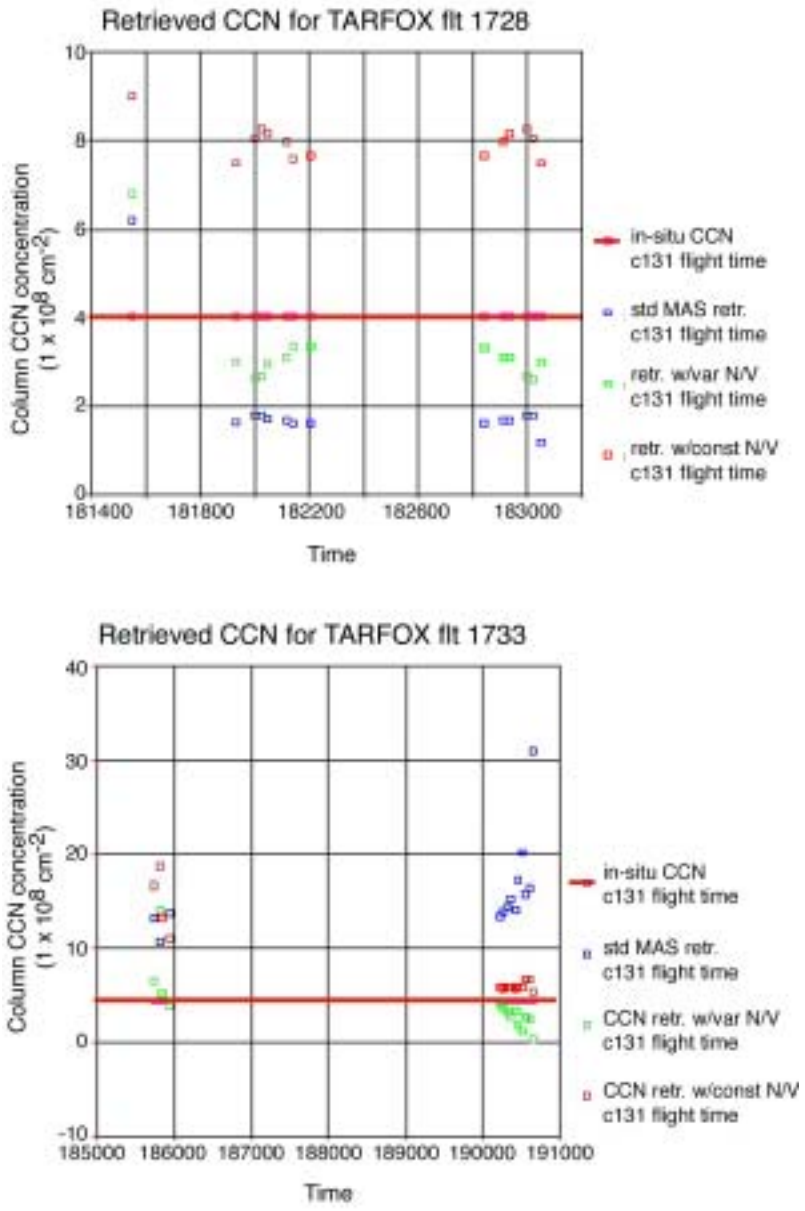

Figure 3: Comparison of retrieved CCN concentration from MODIS using three different parameterizations with in-situ measurements from TARFOX. (a) Case of 7/17/96. (b) Case of 7/24/96. The times shown are the flight times of the UW C-131A aircraft which obtained the in-situ measurements.

- Retrievals of aerosol dry volume and CCN number concentration are significantly improved by taking into account aerosol hygroscopicity as a general variable, and, indeed, also treating the aerosol scattering efficiency as a variable.

In the next two years, we hope to relate measured aerosol composition with concurrently measured aerosol hygroscopicity and optical properties. Further, we hope to assess how changes in the aerosol composition due to in-situ chemical reaction effects the aerosol hygroscopicity and associated optical properties.

REFERENCE

None.

PUBLICATIONS

None.

PATENTS

None.